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PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Julian Glyn BALSDON and Sean Alan WALTERS

Application No.: New U.S. Security Patent Application

Filed: October 28, 1998 Docket No.: 101846

For: IMPROVEMENTS IN OR RELATING TO A BLADE TIP CLEARANCE SYSTEM

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CLAIM FOR PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The benefit of the filing date of the following prior foreign application filed in the following foreign country is hereby requested for the above-identified patent application and the priority provided in 35 U.S.C. §119 is hereby claimed:

Great Britain Patent Application No. 9725623.4 filed December 3, 1997

In support of this claim, a certified copy of said original foreign application:

X is filed herewith.

_____ was filed on _____ in Parent Application No. _____ filed _____.

It is requested that the file of this application be marked to indicate that the requirements of 35 U.S.C. §119 have been fulfilled and that the Patent and Trademark Office kindly acknowledge receipt of this document.

Respectfully submitted,

James A. Oliff
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PATENTS ACT 1977

CONDITIONAL PERMIT FOR FILING A PATENT APPLICATION OUTSIDE THE UNITED KINGDOM

Application No. GB9725623.4

Filed 3 December 1997

On **16 December 1997** directions were given under Section 22(1) prohibiting publication of information contained in the above-numbered application for defence reasons. The directions are still in force, but the applicant is hereby authorised to apply in **THE UNITED STATES OF AMERICA** for grant of a patent in respect of matter contained in the application, subject to the conditions set forth below:-

(1) The application has been classified by a defence authority of the United Kingdom as **UK RESTRICTED** and the receiving Government shall be requested to place the corresponding application in secrecy and accord it at least the equivalent security classification.

(2) The corresponding application shall be abandoned if this action becomes necessary to ensure secrecy.

(3) All correspondence relating to the corresponding application shall be transmitted solely through officially recognised adequately secure communication channels. All persons in the receiving country required to deal with the patent application there shall have been authorized to have access to such security classified information and be able to provide adequate physical security.

(4) The applicant shall make available to the receiving Government for defence purposes a copy of the application filed in that country.

This permit applies only to matter disclosed in the United Kingdom application, and it does not authorise the making of an application under the European Patent Convention or the Patent Cooperation Treaty.

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I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

I further certify that pursuant to Section 22(1) of the Patents Act, 1977, the Comptroller has ordered prohibition of publication of the said specification.

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1.	Your reference	PAT/VJB/2611
2.	Patent application number *(The Patent Office will fill in this part)*	**9725623.4**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	ROLLS-ROYCE plc 65 BUCKINGHAM GATE LONDON SW1E 6AT GREAT BRITAIN
	Patents ADP number *(if you know it)*	
	If the applicant is a corporate body, give the country/state of its incorporation	GREAT BRITAIN
4.	Title of the invention	IMPROVEMENTS IN OR RELATING TO A BLADE TIP CLEARANCE SYSTEM
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	MR V J BIRD PATENTS DEPT EW 1-5 ROLLS-ROYCE plc PO BOX 3 FILTON BRISTOL BS34 7QE
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		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

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7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* — YES
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	0
Request for preliminary examination and search *(Patents Form 9/77)*	YES
Request for substantive examination *(Patents Form 10/77)*	NO
Any other documents *(please specify)*	NONE

11. I/We request the grant of a patent on the basis of this application.

Signature Date 2 December 1997

V J BIRD - AGENT FOR THE APPLICANT

12. Name and daytime telephone number of person to contact in the United Kingdom — MR V J BIRD 0117 979 7137

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IMPROVEMENTS IN OR RELATING TO A BLADE TIP CLEARANCE SYSTEM

This invention relates to improvements in a blade tip clearance system for a rotary stage of a gas turbine engine. In particular, the invention concerns improvements in a blade tip clearance system for a turbine stage and which is driven by fluid pressure in an internal air cooling system associated with the stage.

Our published UK patent specification GB 2169962A discloses a tip clearance control system that uses fluid pressures. In this arrangement, a movable diaphragm member supports shroud liner segments of a compressor rotary stage. Behind the diaphragm member is a chamber. Pipe work connects the chamber to a valve that connects the chamber alternatively with a source of fluid pressure or vents the chamber to a low pressure region. Thus, displacement of the diaphragm, by controlling the pressure in the chamber, moves the shroud liner segments. However, the additional pipe work and diaphragm add weight and introduce other components with their own associated risks of failure.

It is also known to produce a tip clearance control system operated by differential air pressure. Such a control system has an annular arrangement of movable shroud liner segments which forms the inner circumference of an annular pressure chamber encircling the blades of a rotary stage. High pressure air is bled into the chamber from a source of high pressure compressor delivery air through small holes. The chamber is typically vented rapidly through an electrically controlled valve into the engine bypass duct. When the valve is opened, pressure in the chamber drops quickly below gas path pressure to move the shroud liner segments radially outwards, thereby increasing blade tip clearance. In this system, during engine operation, fluid (ie air) is bled continuously into the plenum chamber. The fluid will usually be drawn from a source of high pressure compressor delivery air.

The present invention seeks to provide improvements to the above system whereby hot gas ingestion into the plenum chamber is minimised when the plenum chamber is at a low pressure, especially under extreme performance conditions such as slow acceleration. This is particularly important if the valve and actuation system are designed to fail in an open configuration.

According to the present invention there is provided a pressure actuated tip clearance system for a shroud structure of a gas turbine rotary stage including an annular plenum chamber formed between an annular arrangement of a plurality of shroud liners on the inner circumference of the chamber and a generally cylindrical casing on the radially outer side, and, in use, a hot gas stream located radially inwards of the shroud liners, wherein each shroud liner comprises a hollow box section comprising upstream and downstream walls, radially inner and outer walls, and side walls, the downstream wall and radially inner and outer walls being closed, the upstream wall having an air inlet aperture, and at least one of the side walls having at least one outlet aperture, and the inlet aperture is in flow communication with a source of high pressure air at a pressure higher than that of the hot gas stream.

The invention will now be described by way of example only with reference to the accompanying schematic drawings, in which:

Figure 1 is a radial section through a shroud liner arrangement of a turbine stage of a gas turbine engine according to the invention;

Figure 2 is an axial view on line II-II of Figure 1;

Figure 3 is a radial section through an alternative shroud liner arrangement of a turbine stage of a gas turbine engine, similar to that of Figure 1, but further showing a transfer means for delivering high pressure compressor delivery air to the shroud liner arrangement; and

Figure 4 is an end view of the transfer means of Figure 3 taken in the direction of arrow IV.

It will be understood that the drawings are not to scale and that, in particular, the depiction of the gaps between facing surfaces has been exaggerated in the interest of clarity.

Referring now to Figure 1, there is shown a radial view through part of the first, high pressure turbine stage of a bypass gas turbine aeroengine. A section of a generally cylindrical engine outer casing is indicated schematically at 2, and an adjacent section of a concentric inner casing, likewise schematically. An annular space 6 between the outer and inner casings 2,4 constitutes the engine bypass duct. On the left (upstream) side of Figure 1 is shown part of an upstream nozzle guide vane 18 extending radially across a hot gas path 3 between an outer vane platform 16 and a concentric inner vane platform (not shown). As will be understood, the illustrated guide vane 18 is one of a series of guide vanes extending radially between the concentric vane platforms and which together with the platforms from the outlet nozzle guide vane annular. The inner surfaces (ie those facing into the gas flow 3) of the vane platforms are smooth-flow walls.

An annular volume 19 formed by the space between the outer vane platform 16 and the inner casing 4 constitutes a chamber which opens into the high pressure casing surrounding the engine combustion chamber. The air in annular volume 19 is always at a higher pressure than the gas stream.

Downstream of the outlet nozzle guide vane annulus is a high pressure turbine rotary, stage 20 consisting of an annular array of shroudless turbine blades 22 (only one of which is shown in part) mounted on a disc (not shown). Encircling the array of turbine blades 22 is an annular arrangement consisting of a plurality of shroud liner segments 24 (only one of which is shown) mounted in side by side abutment in a circumferential direction. Each shroud liner segment 24 carries on its radially inner

face a layer 26 of abradable material into which the tips of the blades 22 can wear a track, or groove, in the event of a transient tip rub occurring. The construction of the shroud liner segment 24 will be described in more detail hereinafter.

Downstream of the turbine blades 22 in the gas path 3 is a second annular array of guide vanes 36 (only one of which is shown) extending radially between an outer vane platform 34 and an inner vane platform (not shown), and spaced apart in a circumferential direction.

In an assembled arrangement, upstream and downstream circumferential edges of the shroud liner segment 24 are supported by portion of the guide vane outer platforms 16,34 respectively. Specifically, the upstream outer platform 16 has a trailing edge 38 which extends downstream and acts as a stop for the upstream circumferential edge of the shroud liner segment 24. The downstream outer platform 34 likewise has an upstream extending margin 44 which acts as a stop for the downstream circumferential edge of the shroud liner segment 24.

A short distance upstream from trailing edge 38 is formed an upstanding circumferential flange 40 which extends radially outwards from the vane platform 16 towards the inner engine casing 4 and also forms the downstream containing wall for the annular volume 19. At a height intermediate between the outer platform 16 and the inner engine casing 4 the flange 40 is provided on its downstream side with an axially extending projection or stop 42 which is thus parallel to but spaced from the guide vane trailing edge 38. Similarly, a short distance downstream from margin 44 of outer vane platform 34 there is formed an upstanding circumferential flange 48 extending radially outwards from platform 34 and provided at an intermediate height on its upstream side with an axially extending projection or stop 46 which is thus parallel to but spaced from the margin 44. Hence, the liner segment 24 is restrained in its radial movement by the pairs of stops 38,42 and 44,46. The liner segments 24 constitute a movable inner wall of an annular plenum chamber 50 which is bounded radially by the liner segments and the inner engine casing 4. The radial movement of

the shroud liner segments 24 in response to thermal and centrifugal changes in radial dimension of the turbine blades 22 may be controlled by means known in the art but which need not be illustrated or described herein for the purposes of the present invention.

The detail structure and operation of shroud liner segment 24 will now be described with reference to Figures 1 and 2.

The shroud liner segment 24 is a cuboid box structure 60,62 and a closed downstream wall 64. The upstream wall 66 has at least one aperture 68 (two are in fact shown in Figure 2) providing flow communication between the upstream exterior of the liner segment 24 and its interior, and lying parallel to the engine axis (chain line 5). Side walls 70,72 of the liner segment 24 have at least one aperture 74 (three are shown in Figure 1) providing flow communication between the interior of the liner segment and the exterior.

The circumferential flange 48 is provided with a series of axial apertures 76, each in approximate axial alignment with a corresponding aperture 68 in the shroud liner segment 24, thus enabling cool high pressure compressor air to pass from the annular volume 19 into the apertures 68. Hence, high pressure compressor air entering the liner segment 24 through aperture(s) 74 from the annular volume 19 will exit through aperture(s) 68. The cross-sections of apertures 76 and 68 will be chosen so that despite the radial position of the shroud liner segment 24 there will be a sufficient overlap between the apertures 76 and 68 for high pressure compressor air to flow therethrough.

In Figure 2, the shroud liner segments 24 are shown circumferentially adjacent, separated by radial gaps 78 into which the apertures 74 feed. Some measure of sealing of these radial gaps 78 is effected by seal strips 80 which insert into corresponding slots 82 in walls 70 and 72 of the shroud liner segment 24. However, perfect sealing is not attainable because there will be movement of the sealing strips

80 in the slots 82 due to relative radial movements of the shroud liner segment 24, and there will be a natural tendency for hot, high pressure gas from the gas stream 3 to pass along the radial gaps 78 into the relatively low pressure plenum chamber 50. This will effectively be inhibited by the cool high pressure compressor air flowing from the apertures 74 into ,and pressurising, the radial gaps 78, some air encasing into the plenum chamber 50, and some into the gas stream 3.

There are provided small bleed holes 84 leading from annular volume 19 through the outer vane platform 16 to a clearance gap 86 between the upstream face of a radially inner portion of the shroud liner 24 and the trailing edge 38 of the vane platform. There exists a permanent pressure gradient between the annular volume 19 and the gas path 3, and this will drive a flow of cooler air through holes 84 into the clearance gap 86 and thus provide a shield against incursion of hot gas from the gas path 3 past the shroud liner 24 into the plenum chamber 50.

There are also provided bleed holes 88 leading from the interior of the shroud liner 24 to a radially outer portion of the clearance gap 86. Some of the cool high pressure compressor air that has passed into the shroud liner 24 from the annular volume 19 will escape through the bleed holes 88 and assist in providing a shield against the incursion of hot gas from the gas path 3 into the plenum chamber 50.

Referring now generally to Figure 3 there is shown an alternative shroud liner arrangement in which features identical to those of Figures 1 and 2 have the same numbering.

Aperture 68 in wall 66 of shroud liner 24 has a frusto-conical section 90 at its downstream end, of tapering cross-section in the downstream direction to a narrow exit 91 into the interior of the shroud liner.

Located with aperture 68 in the shroud liner 24 and aperture 76 in flange 40 is a transfer tube 92 which spans the radial gap between the shroud liner and the flange.

The transfer tube 92 is of generally cylindrical construction and is provided with external radiussed circumferential flanges 94,96 at either end, as can also be seen from the end view of the transfer tube 92 in Figure 4. Flange 94 at the upstream end of the transfer tube contacts the interior of aperture 76, and flange 96 at the downstream end contacts the frusto-conical surface 90. Because the circumferential flanges 94,96 are radiussed, they roll against the respective interior surfaces of apertures 76 and 68 as the shroud liner 24 moves, in use, in relation to static components such as flange 40, thereby providing the transfer tube with up to 6 degrees of freedom.

The transfer tube 92 thus acts to p provide an efficient means for transferring high pressure compressor air from the annular volume 19 to the interior of the shroud liner 24 under all relative dispositions of the shroud liner with respect to the flange 40.

Aperture 76 in flange 40 is provided at its upstream end (ie the opening into the annular volume 19) with a radially inwardly directed circumferential retaining flange 98 which acts to limit axial movement of the transfer tube 92 in the upstream direction. Axial movement of the transfer tube 92 in the downstream direction is of course limited by the tapering section 90 of aperture 68.

The transfer tube 92 is also provided with a tapering internal section 99 at its downstream end so as to ensure an efficient flow of air from the transfer tube through the exit 91 into the interior of the shroud liner 24.

There may be two or more transfer tubes 92 per shroud liner 24.

In addition to the high pressure air fro annular volume 19 entering the shroud liner 24 and exiting therefrom via apertures 74 and 88 to provide a shield against leakage of hot gas fromthegas stream 3 past the shroud liner into the plenum chamber 50 the high pressure air entering the shroud liner has a beneficial cooling effect on the shroud liner and surrounding structures.

In some embodiment it may be considered sufficient to have one or more apertures 74 in only one of the sides 70,72 of each shroud liner 24.

In a further possible embodiment (not illustrated) the transfer tube may be a flexible (eg corrugated) structure fixed at one end to aperture 76 and at the other to inlet 88.

CLAIMS

1 A pressure actuated tip clearance system for a shroud structure of a gas turbine rotary stage including an annular plenum chamber formed between an annular arrangement of a plurality of shroud liners on the inner circumference of the chamber and a generally cylindrical casing on the radially outer side, and, in use, a hot gas stream located radially inwards of the shroud liners, wherein each shroud liner comprises a hollow box section comprising upstream and downstream walls, radially inner and outer walls, and side walls, the downstream wall and radially inner and outer walls being closed, the upstream wall having an air inlet aperture, and at least one of the side walls having at least one outlet aperture, and the inlet aperture is in flow communication with a source of high pressure air at a pressure higher than that of the hot gas stream.

2 A tip clearance system as claimed in claim 1 wherein the flow communication includes an aperture in a wall enclosing high pressure air, said aperture being adjacent to an in at least approximate alignment with the inlet aperture.

3 A tip clearance system as claimed in claim 1 or 2 wherein the source of high pressure air is a high pressure compressor air delivery system.

4 A tip clearance system as claimed in any preceding claim wherein the at least one outlet aperture is directed into a radial gap between two adjacent shroud liners so that high pressure air within the shroud liner, in use, exits through said outlet aperture and inhibits hot gas from passing radially outwards between the shroud liners into the plenum chamber.

5 A tip clearance system as claimed in any preceding claim wherein circumferentially adjacent shroud liners are linked by one or more seal strips

extending across a radial gap between adjacent shroud lines, each seal strip being housed at each end in a slot in a side wall of a said shroud liner, the housing in the slots being arranged to permit relative radial movement of adjacent shroud liners.

6 A tip clearance system as claimed in claim 2 wherein there is provided an air transfer tube between the aperture in the wall enclosing the high pressure air and the inlet to the shroud liner, the transfer tube being arranged to move in response to radial movement of the shroud liner.

7 A tip clearance system as claimed in claim 6 wherein the air transfer tube comprises a cylindrical structure having its upstream end inserted into the aperture in the wall enclosing the high pressure air and its downstream end inserted in the inlet to the shroud liner, the inlet to the shroud liner having a frusto-conical section tapering downstream, and the transfer tube being provided at both ends with external circumferential radiussed flanges, the upstream flange being in rolling contact with the wall of said aperture and the downstream flange being in rolling contact with the frusto-conical section of said inlet, whereby the transfer tube is able to move with several degrees of freedom in response to radial movement of the shroud liner.

8 A tip clearance system as claimed in any preceding claim wherein there is further provided a bleed aperture leading from the interior of the shroud liner to a radial clearance gap immediately upstream of the shroud liner and extending from the gas stream to the plenuy chamber, whereby, in use, high pressure air from within the shroud liner exits through the bleed aperture and inhibits the passage of hot gas from the gas stream into the plenum chamber.

9 A tip clearance system as claimed in claim 8 wherein there is provided a high pressure bleed system leading from the source of high pressure air to said radial clearance gap, whereby, in use, high pressure air bleeds into the

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clearance gap and inhibits the passage of hot gas from the gas stream into the plenum chamber.

10 A tip clearance system as claimed in any one of claims 1 to 7 wherein there is provided a high pressure bleed system leading from the source of high pressure air to a radial clearance gap immediately upstream of the shroud liner and extending from the gas stream to the plenum chamber whereby, in use, high pressure air bleeds into the clearance gap and inhibits the passage of hot gas from the gas stream into the plenum chamber.

11 A pressure actuated tip clearance system substantially as hereinbefore described with reference to figures 1 and 2 or 3 and 4 of the accompanying drawings.

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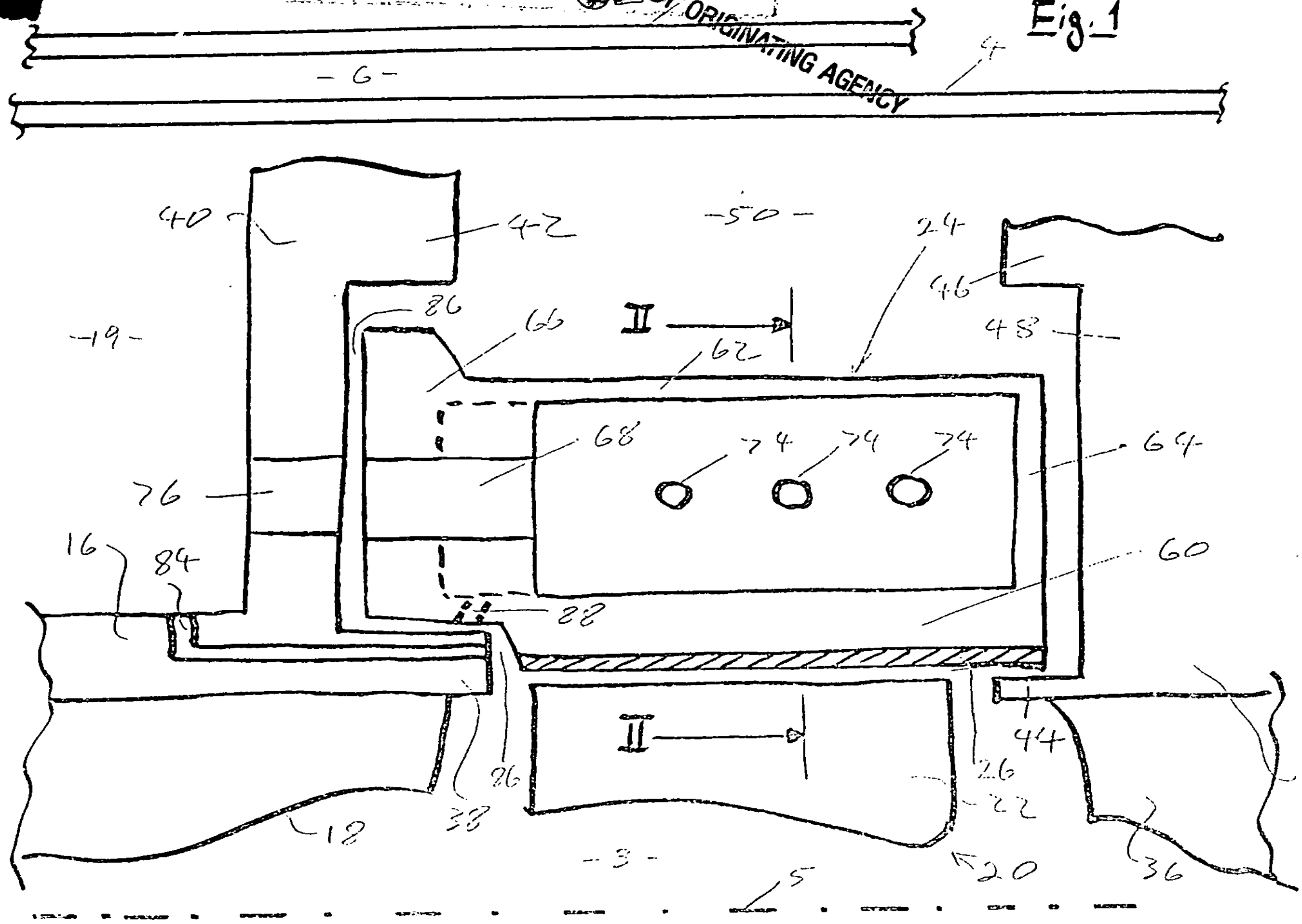
ABSTRACT

IMPROVEMENTS IN OR RELATING TO A BLADE TIP CLEARANCE SYSTEM

A pressure actuated tip clearance system for a shroud structure of a gas turbine engine rotary stage includes an annular plenum chamber formed between an annular arrangement of a plurality of shroud liners on the inner circumference of the chamber and a generally cylindrical casing ontheradially outer side, and, in use, a hot gas stream radially inwards of the shroud liners. Each shroud liner comprises a hollow box section comprising upstream and downstream walls, radially inner and outer walls, and side walls, the downstream and radially inner and outer walls being closed, the upstream wall having an air inlet aperture, and at least one of the side walls having at least one outlet aperture. The inlet aperture is in flow communication with a source of high pressure air at a pressure higher than that of the gas stream.

Fig. 1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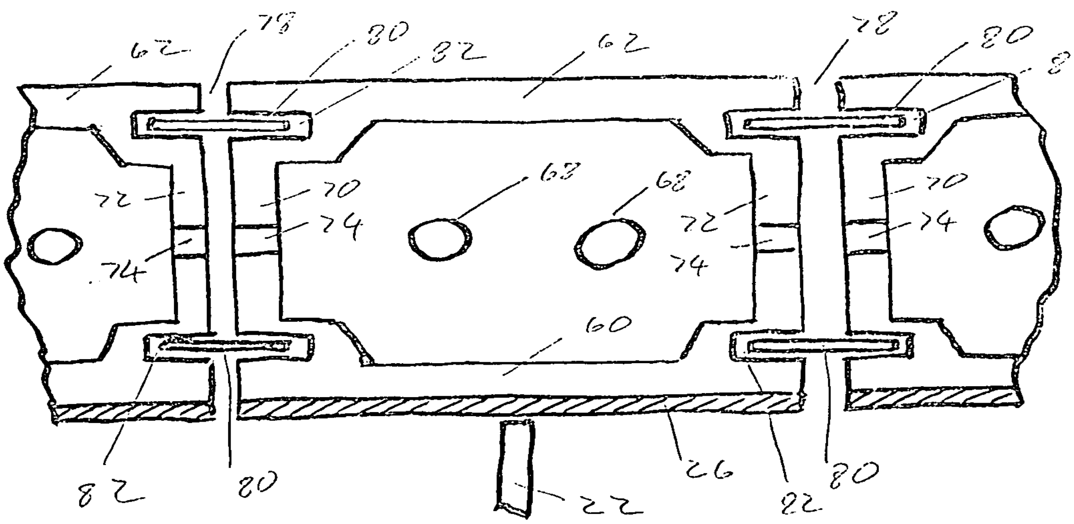
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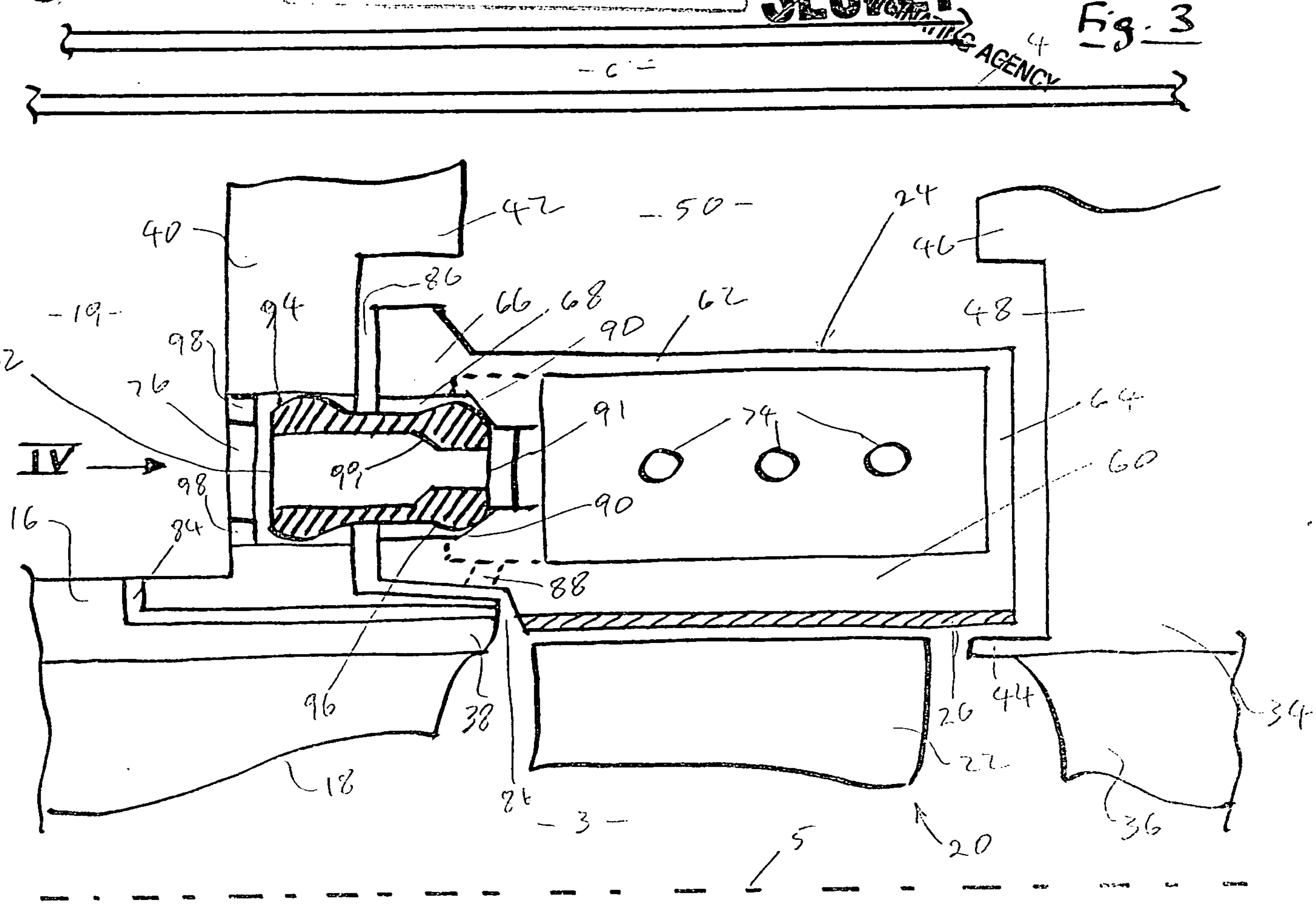
Fig. 2

Fig. 3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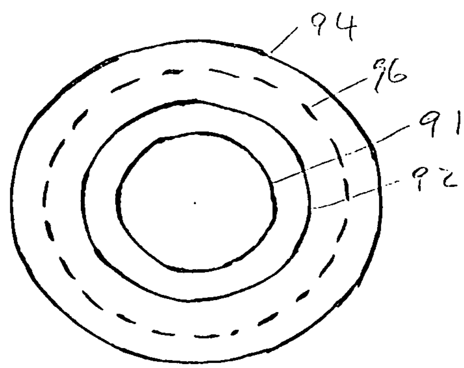
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Fig. 4